Integrated Computational Materials Engineering (ICME) and In-situ Process Monitoring for Rapid Qualification of Components Made by Laser-Based Powder Bed Additive Manufacturing (AM) Processes for Nuclear Structural and Pressure Boundary Applications

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ABSTRACT:

Nuclear power plant equipment manufacturers have realized the potential to deploy additive manufacturing (AM) methods to produce reactor internal components due to its unique capability to generate complex geometries rapidly with improved performance, while reducing the cost and time to market. In this proposed U.S. Department of Energy (DOE) project, an innovative "qualification strategy for complex nuclear parts" produced by laser powder bed AM will be developed and demonstrated by leveraging relevant technology from recent welding developments, as well as, emerging process analytics, high-performance computation models, *in-situ* monitoring and big-data mining. Data generated utilizing this approach can be shared with stakeholders/Original Equipment Manufacturers to determine risks involved in deployment of components in nuclear applications – directly relevant to the mission of the NEET Program.

The project scope involves six tasks involving design, processing with *in-situ* monitoring, deployment of high performance computational model, *ex-situ* characterization, scale up of components, and compilation of methodology and data package for standards organization approval. The approach proposed in this project will lead to a generation of a live data package for each individual component produced by powder bed additive manufacturing process intended for nuclear application. The data package essentially provides a nuclear qualification for each individual part.

Innovative manufacturing methods for nuclear applications are central to the NEET-1 program. Laser-based power bed AM processes have the potential to develop an entirely new field for manufacturing nuclear internal components. Coupling the technology with ICME and *in-situ* process monitoring can provide industry with a qualification strategy and approach to assure nuclear grade quality can be met. Specifically, the overall methodology combines process sensing, control, nondestructive inspection, and integrated computational materials engineering (ICME).

The deliverables of this proposed research will include the following: (a) designs that will allow for laser powder bed AM of complex components; (b) fabrication of three components by AM, as well as, a traditional manufacturing process; (c) ICME process analytical methods to fuse the modeling, process, *in-situ* and *ex-situ* characterization data through Dream3d architecture; and (d) data and ICME and *in-situ* process monitoring qualification methodology package to support ASME and regulatory qualification/acceptance.

On demonstration of the ICME-based approach, 100% qualification of additively manufactured components using the methodologies, as well as deployment of the same within the participating industries, we would significantly have addressed the gaps associated with additive manufacturing based fundamental scientific understanding of spatial and temporal variations of thermal cycles. With the successful completion of this project, we would have demonstrated that the laser powder bed additive manufacturing can indeed manufacture nuclear components with robust quality and performance attributes.

This project is a collaborative effort between ORNL-UTK, Westinghouse, Rolls-Royce and EPRI. This diverse collaboration will ensure this project will have near-term impact and relevance to the nuclear industry and project results will be used by industrial partners to fabricate reactor internals and other nuclear components. By enabling additive manufacturing of existing component designs through ICME based qualification with limited testing, we can address the reduction of cost and delay.